USING TASK ANALYSIS TO UNDERSTAND THE DATA SYSTEM OPERATIONS TEAM

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ABSTRACT
The Data System Operations Team (DSOT) currently monitors the Multimission Ground Data System (MGDS) at NASA's Jet Propulsion Laboratory. The MGDS currently supports five spacecraft and within the next five years it will support ten spacecraft simultaneously. The ground processing element of the MGDS consists of a distributed UNIX-based system of over 40 nodes and 100 processes. The MGDS system provides operators with little or no information about the system's end-to-end processing status or end-to-end configuration. The lack of system visibility has become a critical issue in the daily operation of the MGDS. A task analysis was conducted to determine what kinds of tools were needed to provide DSOT with useful status information and to prioritize the tool development. The analysis provided the formality and structure needed to get the right information exchange between development and operations. This paper describes how even a small task analysis can improve developer-operator communications and examines the challenges associated with conducting a task analysis in a real-time mission operations environment.

INTRODUCTION

Any human factors engineer would leap at the opportunity to conduct a task analysis for a project. Likewise, project managers would appreciate any opportunity to gain insightful information about their customer's needs and what products will meet those needs. Still task analyses are not typically incorporated into the software development life cycle. This absence is especially odd since system development is a highly interactive process.

The system development process is usually considered a logical, intellectual process, but it often contains many "irrational and nonintellective elements" (Meister, 1971). Even with a good understanding of task analysis methods and their proper application, the analysis may still be subject to other influencing factors like time, budget, and (most importantly) the cooperation of engineers (Meister, 1991). However, even a small task analysis reveals useful information and insight that would otherwise go unnoticed if no analysis was done at all.

THE SYSTEM

The task analysis described in this paper was conducted to understand the daily activities of the Data System Operations Team (DSOT) who are responsible for running the Multimission Ground Data System (MGDS). The MGDS provides spacecraft telemetry data capture, data processing and display, and system monitor and control capabilities. Data is received into the system from the spacecraft via the Deep Space Network (DSN). The DSN is a network of antennas through which commands are sent to the spacecraft and data is received from the spacecraft and forwarded to the MGDS. The Data System Operations Team monitor the data from the DSN and follow it closely as it is processed through the MGDS and delivered to project scientists, spacecraft teams, NASA centers, principal investigators and other end users (Figure 1).

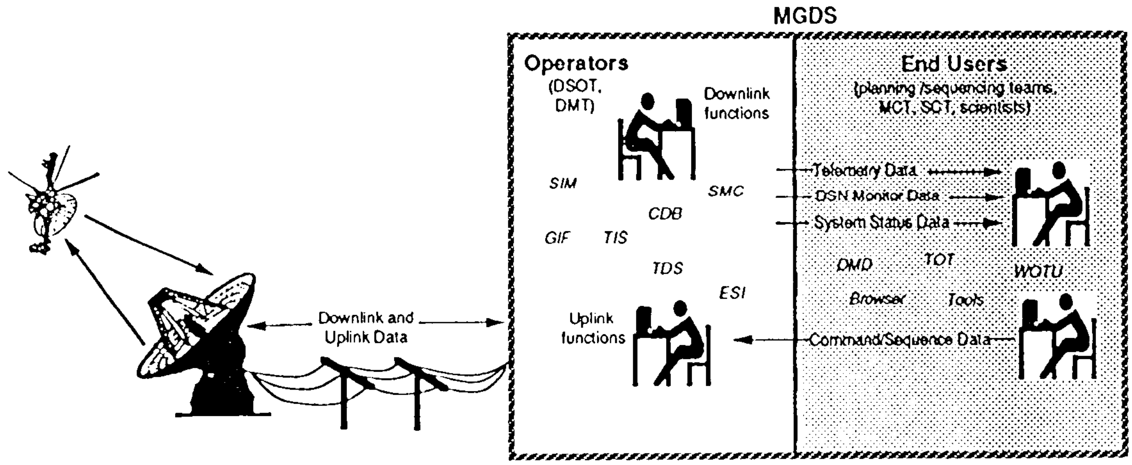

Figure 1. MGDS Operators Keep MGDS Running So End Users May Receive Data and Command the Spacecraft

DSOT primarily focuses on the MGDS itself and how it is functioning, as well as the packaging, routing, and storing of the data, rather than with actual data values and their significance (Miller et al, 1992). Operators rely on experience, teamwork and existing tools to monitor the system and get the data to the system users.

Figure 2 shows a simplified MGDS end-to-end data flow. Running the front-end of the system is labor intensive and difficult. It's labor intensive because the setup for a DSN tracking pass-configuring the processing of the data through the system-is a manual process.

Although some of the setup activities are scripted, they are not automated at startup, and once running there is no mechanism for managing the hierarchy of activities. The process is difficult because there are no tools that provide data accountability or visibility into front-end data processing. For example, DSOT has no tool that estimates the amount of data (by type) a project is expecting from a given track for all the project's data types; nor is there a way to estimate what the output products should be across the front-end subsystems.

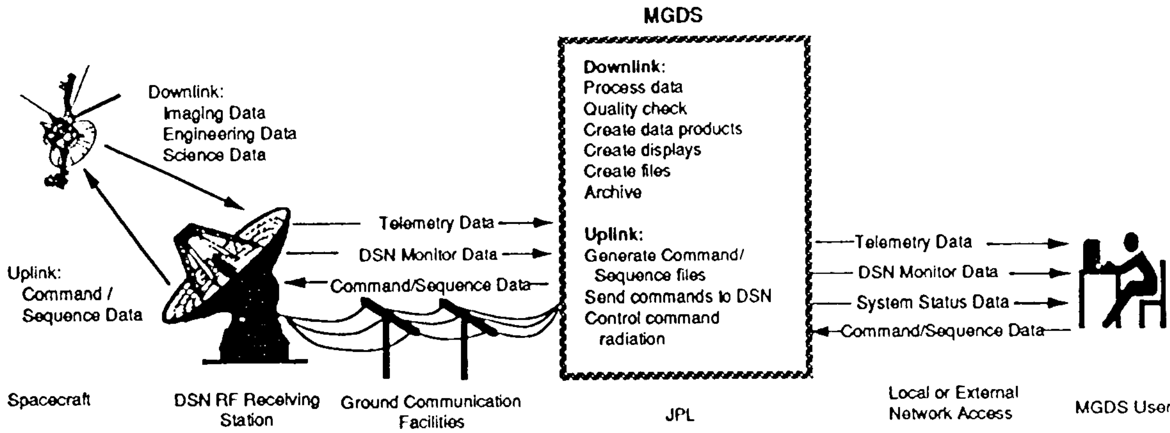

Figure 2. Simplified End-To-End MGDS Data Flow

In order to reduce operations costs through improved efficiency in DSOT, an initiative called DSOT Cockpit was funded to address the special needs of the DSOT operators. The goal of DSOT cockpit was to provide much-needed visibility into the system's front-end processing where DSOT operations are focused. Tools that display information about the current and expected system status are key elements of the DSOT cockpit effort to improve mission operations. The lack of system visibility is critical to mission operations because when a flight project suddenly stops receiving data, DSOT must find the problem and solve it in real-time. The tools needed to *see* what is happening in the system did not exist. The task analysis was conducted to identify what tools were needed and to prioritize development of those tools.

TASK ANALYSIS

Fortunately, management had a good understanding of what a task analysis entailed and what to expect from it. Getting both development and operations management support was not as difficult as originally anticipated. Before the analysis began, managers were briefed on the purpose of *this* task analysis and what they could realistically expect to find from it. The development side agreed to implement the tools according to the findings in the analysis.

In the interest of time and resources, the task analysis had to be fast, be efficient, and produce reliable results. At a minimum, the results needed to recommend solutions that were as good as or better than those that the developers had come up with on their own. It also needed to accurately reflect the daily tasks of DSOT in terms developers could understand and recommend ways to improve DSOT operations.

One particular challenge was finding a standard task analysis format for real-time mission operations. There isn't one. The closest thing to a standard is the *Handbook for Designers of Instructional Systems*. The goals of this analysis had to be considered and the methods had to be selected, adapted, or developed from the Handbook. At first it seemed overwhelming, but it quickly became clear that for any task analysis, there will be diverse variables that will influence the analysis, design, methods of data collection, and the resulting design recommendations. The process of selecting the task analysis methods and format for DSOT took longer than expected but was worth the effort.

Methods

The primary methods of data collection were individual interviews and observations of work activities. These methods were selected because they were simple, fast, and minimally disruptive during operations. The interviews were conducted at the individual operators' workstations, so the operators were not removed from their work areas. There was only one instance of an interview having to be rescheduled because of a system problem that required immediate attention.

The original task analysis proposal stated that all operators would be interviewed, however because of resource constraints only a random sample of the team could be interviewed. The sample was selected by randomly selecting names from a list of operators. A total of 10 operators were interviewed.

links are small, $R_nA \approx 5 \times 10^{-10}$ Ω-cm^2 at 4.2 K, so that 0.1 µm lithography will be required to produce 5 Ω devices.

N-YBCO WEAK LINKS

The edge formation and cleaning process just described provides the basis for fabrication of HTS weak links using deposited epitaxial normal metals. One possible SNS device technology uses a nonsuperconducting phase of $YBa_2Cu_3O_{7-x}$ (N-YBCO) as the normal metal. Some results on fabrication and testing of N-YBCO weak links have been presented previously (15,16). Here we examine new data on N-YBCO characterization and N-YBCO device results, including the scaling behavior of the weak link critical current densities and I_cR_n products.

The N-YBCO thin films are deposited using a standard laser ablation process and a nearly stoichiometric $YBa_2Cu_3O_{7-x}$ target, except that the films are grown at ≈ 530 C, a much lower temperature than typically used to produce high quality superconducting YBCO thin films. Because of the difficulty of characterizing N-YBCO films deposited on the very small area YBCO base electrode edge, characterization of these films has been done primarily on N-YBCO layers grown directly on $LaAlO_3$ substrates, followed by a 1-2 minute anneal at ≈ 800 C, to mimic the counterelectrode growth conditions. Lateral transport resistivity measurements on 100 Å N-YBCO thin films grown in this manner show semiconductor-like behavior, although in some cases a drop in resistance is seen near 4 K. Resistivity measurements on much thicker N-YBCO films (3000 Å) show a superconducting transition at ≈ 40 K. X-ray diffraction studies of 500 - 1000 Å thick N-YBCO show peaks consistent with orthorhombic $YBa_2Cu_3O_{7-x}$ with a c-axis lattice constant of 11.68 Å. X-ray photoelectron spectroscopy (XPS) measurements on N-YBCO films produced with the above annealing procedure show no obvious difference from standard orthorhombic $YBa_2Cu_3O_{7-x}$. Finally, preliminary high resolution cross-sectional transmission electron microscopy (HRTEM) studies give images consistent with an orthorhombic YBCO phase.

These measurements demonstrate that N-YBCO is not the semiconducting cubic phase of YBCO reported by Agostinelli et al. (25). The characterization studies also indicate that N-YBCO is probably not the the nonsuperconducting oxygen-rich (26) or oxygen-poor (27) tetragonal phases reported earlier, because these phases exhibit c-axis lattice parameters smaller or larger than the value of 11.68 Å measured from the x-ray diffraction data. It appears most likely that N-YBCO is orthorhombic $YBa_2Cu_3O_{7-x}$ with oxygen disorder suppressing the transition temperature. A number of studies have shown that YBCO is especially susceptible to oxygen movement and that oxygen disorder can significantly affect T_c (24,28,29). Presumably, crystallization of the low-temperature-deposited YBCO film occurs during the heating ramp to the counterelectrode growth temperature, but sufficient oxygen disorder, and possibly other point defects remain to suppress superconductivity in these films. This supposition is consistent with device results indicating that SNS coupling through N-YBCO is sensitive to the high temperature counterelectrode growth parameters. In particular, we find that weak link current densities increase for hotter counterelectrode growth temperatures. These results suggest that N-YBCO is metastable, and that increased high temperature annealing results in reduced crystalline disorder and stronger weak link coupling. At room temperature, however, the N-YBCO devices are very stable, with almost no change in the current-voltage characteristics after more than a year of storage in an Ar-filled desiccator.

B Branching: Subsequent task options are based on previous task choices.

P Process: Continuous monitoring of a process where the user initiates control movements based on feedback from the system.

Table I. Task Categories and Ratings (Example)

Task/Problem	Task Type	Importance	Difficulty
Data gap detection	B	4	3
End-to-end system configuration information	P	5	5
Post-pass data analysis tool	S	3	2
Show data loss between GIF and TIS	P	5	3

Most of the tasks DSOT conducts are process oriented, making them difficult to analyze. The importance rating was given on a scale of 1-5 with 5 being the most important. The rating was based on the data received from the interviews. Some of the importance ratings were subjective, while others were definitive. The difficulty rating was given on the same 1-5 scale as the importance rating; it was based on developers estimates. Surprisingly, the rated importance of a task or problem varied considerably between operators. This variance was attributed to differences in problem-solving styles and experience.

Another surprise was the general displeasure the operators expressed with the usability and stability of the system. Even when specific problems were not identified, each operator said the system was difficult to learn, use, and operate.

CONCLUSION

This task analysis brought new insight and understanding about operations teams and how individuals use the delivered tools, or adjust to the lack of tools, to run the system. The analysis facilitated constructive communication between development and operations while the analysis was being conducted and has since resulted in more open communications.

The following task analysis tips are based on this experience. They are basic, but they are essential to the use of task analysis as a tool for meeting development and operations goals:

- Define the purpose of the analysis. Task analyses have a variety of purposes; be sure to clearly state which purpose the analysis is aiming to accomplish.
- Be flexible to changes in budget, personnel, or analysis methods. Adaptability is critical to the success of the analysis in a mission operations environment that changes.
- At a minimum, get one person on the development side and one on the operations side to be champions for the analysis. An endorsement will make the analysis run more smoothly and the results will have a better chance of getting implemented.
- Keep everyone informed of the analysis progress or lack of progress. Continuous flow of status information is key to continued support.

Remember, even the simplest analysis can bring more benefit than no analysis brings. It will find hidden problems, highlight strengths, and confirm understandings. It is the key element to making products and systems usable. Task analysis must be included in the development lifecycle (on any scale) in order to develop efficient, usable systems. If you have any doubts, give it a try.

ACKNOWLEDGMENT

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